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AN ATTEMPTED STATISTICAL APPRAISAL OF THE GRAPTOLITE FAUNA OF WILLEY'S QUARRY, VICTORIA, AUSTRALIA

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Abstract

This paper aims to show how easily an atypical collection of fossils (in this case Graptolites) can be made from a locality, and explains how early workers could have obtained anomalous relationships between the forms present. It is intended to be a guide to the collector, pointing out that the true relationships of the forms at a locality can be achieved only by (i) collection of sufficient numbers of specimens, (ii) deliberate random collection, (iii) methodical stratigraphic collection without any gaps.

Introduction

A large number of slabs showing graptolites were randomly collected from Willey's Quarry and their fossil content counted to find the relative proportions of the various forms present. Groups of slabs, varying in number, were drawn off at random to determine whether an erroneous result could be obtained by selective or inadequate collecting.

General

Willey's Quarry is a well known graptolite locality about forty miles from Melbourne, approximately one mile W. of the Calder Highway, Lancefield Military Sheet, one in. to the mile, grid reference 580-841. The quarry is situated in rocks of Yapeen age and is famous for an abundance and diversity of graptolites.

The area was suggested by Dr. O. P. Singleton, Department of Geology, University of Melbourne, as a suitable locality for a trial statistical evaluation of the number of specimens necessary to indicate accurately the relative percentages of the various components of a fauna. However, the author had for some time been aware of the discrepancies between the percentages given by the early workers for the forms at particular localities and those to be found by casual collecting at these same localities. It was thought that this could perhaps be related to the phenomenon, so common in the Ordovician of Victoria, in which some bedding planes are covered by fossils of almost exclusively one species, while adjoining layers contain a sparser and different population, which may even totally exclude the first dominant species.

Methods

A collection of over 90 fossiliferous slabs was made from the quarry dump, where presumably the full sequence of the quarry had been more or less randomly deposited. Random selection was also practised by digging into the dump and moving from place to place over it. Any slab with a recognizable fossil was collected, and afterwards the fossil content identified and numbers of each species counted. Only those specimens which consisted of more than half a rhabdosome of a species, or which contained the sicula were counted (see Fig. 1). This eliminated the possibility of counting more than once an individual broken either before or after burial.

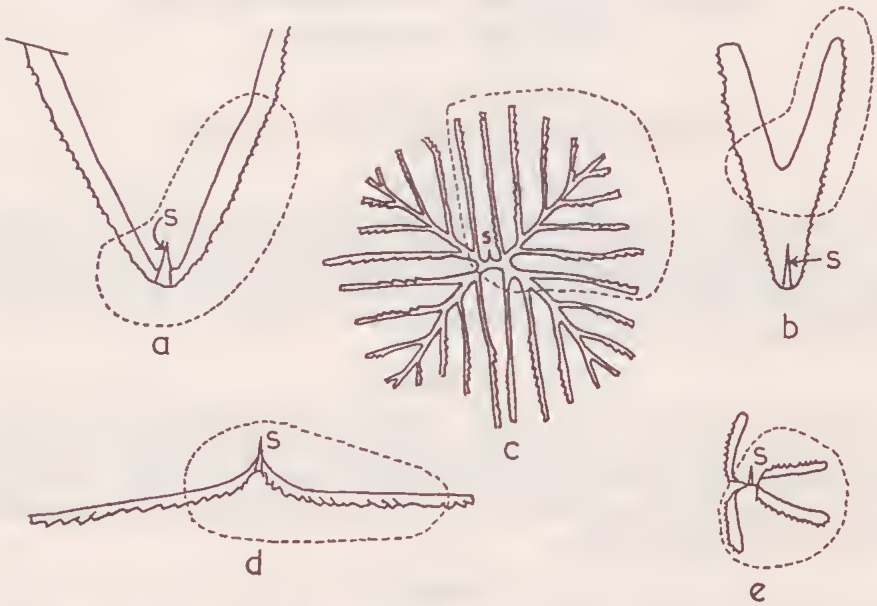

Fig. 1—Shows the portions of graptolite rhabdosomes (within the dotted line) which would be considered sufficient for counting. S indicates the position of the sicula. The figures represent types found at the locality, at about natural size; a. an *Isograptus*, b. *Oncograptus*, c. *Goniograptus*, d. *Didymograptus*, and e. *Tetragraptus*.

The identifications used were those of Harris (1933, pp. 103-104) who tabulated 19 separable species belonging to 11 genera, as well as some un-identifiable forms. The present paper does not claim to substantiate the presence or identification of the species, but merely uses them as forms preferable to an A, B, C, . . . type classification. The descriptions in the same paper were used to separate the various subspecies and here the results with forms like the two subspecies of *Oncograptus upsilon* must be subjective. Some forms were found that could not be referred to any of Harris's listed species, and again some of the forms he identified were not seen, presumably either because of their very small percentage, or because of inadequacies of sampling (see conclusions).

Each slab was numbered and as many graptolites as possible identified on it. When this was done, random (drawn from a hat) brackets of five slabs were made, and the various percentages for each species calculated. The totals of each bracket were consecutively added, and the percentages of the sums to the end of each bracket recorded. In this way it could be seen what percentage of each form appeared in a given number of slabs, i.e. in 20 slabs, 45 slabs, etc., and at what numbers the percentages became statistically stable.

Results and Conclusions

The results were plotted graphically (Fig. 3 shows some typical results) and from these Table I was compiled. In Table I, column (i) shows the number

TABLE I

Forms	(i) Number of slabs per species	(ii) Percentage of all slabs	(iii) Number of specimens per species	(iv) Percentage of fauna	(v) Minimum percentage	Maximum percentage
Tetragraptus quadribrachiatus	4	4·2	4	1·3	2·7–	1·1
Tetragraptus serra	8	8·4	9	2·9	5·5–	0·9
Phyllograptus nobilis	13	4	15	4·9	17 –	4·0
Goniograptus speciosus	2	2·1	2	0·6	14 –	
Trigonograptus ensiformis	4	4·2	4	1·3	1·4–	1·0
Didymograptus v-deflexus	10	11	17	5·5	5·7–	1·5
Isograptus caduceus divergens	33	5	70	3	43 –	21
Isograptus dumosus	12	3	39	3	13 –	3
Isograptus manubriatus	35	7	64	21	39 –	15
Skiagraptus gnomonicus	8	8·4	19	6·2	7·4–	1·8
Oncograptus upsilon	6	6·3	7	2·3	4·1–	1·0
Oncograptus upsilon biangulatus	17	8	47	5	32 –	15
Cardiograptus morsus	6	6·3	6	2	2·0–	1·3
Maeandrograptus tau	1	1·1	1	0·3	0·4–	1·3
Others	1	1·1	1	0·3		

of slabs which contained the various species, and column (ii) these slabs as percentages of the total studied. Column (iii) shows the numbers of the individual species of the fauna, column (iv) the percentage of the total population which consisted of this species, and column (v) the maximum and minimum values obtained during counting. The maximum value is self-evident, the minimum value is the lowest value reached after the first peak (see Fig. 2). Column (iv) shows the percentages calculated from all the specimens collected, and column (v) shows the large discrepancies which could occur with insufficient sampling. Most of the graphs show a fairly rapid tailing-off in variability, and most that the averages calculated, for this number of degrees of freedom, were fairly accurate for a sample of 40 slabs (containing approximately 140 individuals).

A comparison of columns (ii) and (iv) shows another discrepancy. It can be seen that apart from *Didymograptus v-deflexus*, the three isograptid species, *Skiagraptus gnomonicus*, and *Oncograptus biangulatus*, the percentage of slabs which contain a given species is approximately three times the actual percentage of the species in the fauna (what one would expect as the slabs average about three fossils each). But, for the abovementioned species this ratio is closer to unity and in the case of *Isograptus dumosus* is less than unity. This indicates that these species tend to cluster together rather than to occur as individuals in the usual mixed fauna.

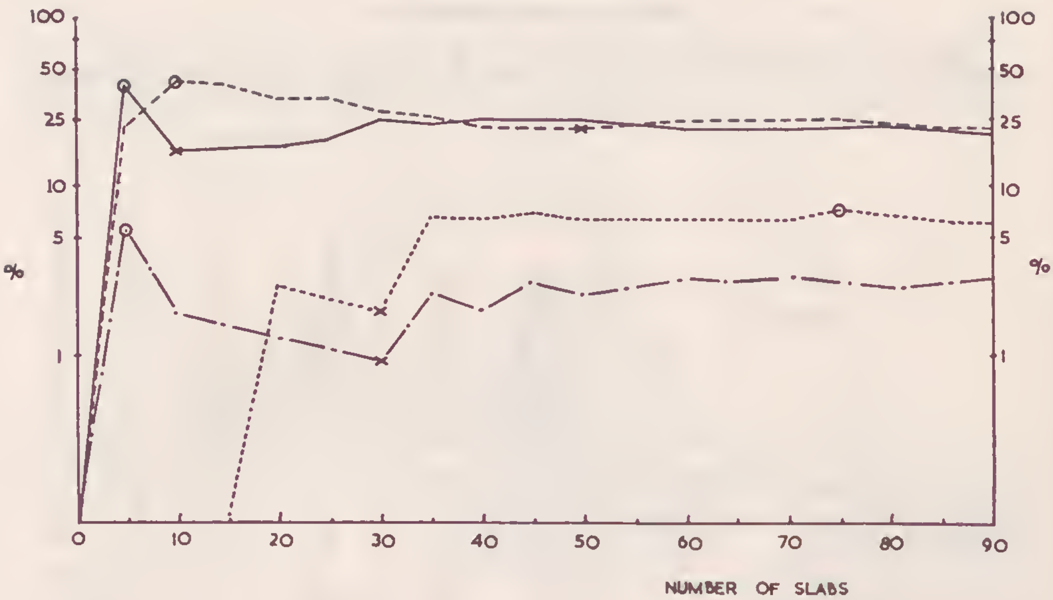

Fig. 2—Shows on semi-log paper, the percentage of the total of four of the forms found, for varying numbers of slabs counted. The percentages are drawn within three logarithmic cycles, 1, 10 and 100. The maximum values are indicated by a circle and the minimum values by a cross. The firm line is for *Isograptus manubriatus*, the dashed line *Isograptus caduceus divergens*, the dotted line *Skiagraptus gnomonicus* and the combined dot and dash represent the values for *Tetragraptus serra*.

Or more quantitatively we can calculate from the natural frequencies a Poisson Distribution and compare the two sets of figures for the various species. The results are similar to those outlined above where most of the species lie fairly close to a Poisson distribution, but for the same five species the curves show pronounced differences from their Poissons. There is a pronounced abundance of slabs (i) without any of the species and (ii) with high counts of the species; thus, the specimens have become grouped together at the expense of the middle values with zero and high counts accentuated. (The goodness of fit of all, or parts of the distributions, can be compared graphically or by the Chi-squared Test. See Appendix for some examples.)

It is this type of block, crowded with specimens not randomly distributed, which catches the eye, and if care is not exercised the collection will certainly not be typical and the population will be biased towards these forms. It is believed that this was the cause of many of the misconceptions of the earlier workers, where populations were estimated as consisting of up to 90% one species.

It is here emphasized that for a true idea of the correct percentage of a species in a population, sufficiently large numbers should be collected and that these should be randomly scattered throughout the section. Should one of these crowded beds be oversampled, by even a small amount, the percentages of a particular form can be markedly increased and should one of these beds be missed, the form, though in fact consisting of a significant percentage, might be overlooked.

Appendix

It can be seen by inspection (from the large frequencies of the lowest class interval), that the distributions would not fit a 'Normal' type distribution; therefore, we must compare them to a Poisson or Binomial distribution. Each of the terms of a Poisson distribution are given by the successive terms of the expansion $e^{-z}\left(1 + z + \frac{z^2}{2!} + \frac{z^3}{3!} + \frac{z^4}{4!} + \ldots\right)$ where z is the expectation for the natural values. Having calculated the terms of the expansion, we can now compare the difference, or better still, the difference squared, divided by the expected (Poisson) value, to see how closely they fit (see Table II). It can be seen that the smallest differences lie in the middle ranges, indicating that the extremes are of much worse fit. We can be more quantitative by working out the Chi-square value for

TABLE II

Class Interval

	0	1	2	3	4	5	6	7	8	9	10	11	12
Natural Frequency	3	2	6	2	1	1	0	1	1	0	1	0	1
Poisson Frequency	0·4	1·6	3·0	3·7	3·4	2·5	1·5	0·8	0·4	0·1	0	0	0
Difference Squared / Expected Value	17	0	3	0·8	1·7	0·9	1·5	0	5 (8–12 grouped)				

$z = 66/18 = 3 \cdot 67$

$e^{-z} = 0 \cdot 0247.$

the curves or parts of them. This is given as the sum of the differences squared divided by the expected value of each term, remembering to group when necessary (see Table II); knowing the number of degrees of freedom involved, this value can be converted to a percentage level of fit. We find that the Chi-square value for the full range is 30, giving a fit well below the 0·1% level. The value in the range 1 to 7 gives 7·9 a 40% level fit, in the range 3 to 7 a 50% fit, etc.

Acknowledgements

The author wishes to thank Dr F. C. Beavis and Mr N. Schleiger for assistance with the manuscript, and especially the latter for help with the mathematical approach. He also thanks the University of Melbourne for paying part of the cost of publication of this paper.

Reference

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